Mesozoic Rocks

By Gordon B. Haxel and David M. Miller

Mesozoic rocks in the East Mojave National Scenic Area (EMNSA) consist of minor Triassic plutons and sedimentary rocks, some volcanic and volcaniclastic Triassic and (or) Jurassic rocks, and Jurassic and Cretaceous plutonic rocks. The Cretaceous plutonic rocks are the most widespread of the Mesozoic rocks in the EMNSA.

Triassic Plutons

Triassic plutonic rocks are widely scattered in regions mostly west and southwest of the EMNSA (Barth and others, 1990; Miller, 1978) and have not yet (1993) been documented in the EMNSA. In the Clark Mountain area, several small dioritic stocks intrude Paleozoic strata, and one of these bodies has yielded K–Ar hornblende ages of 190 and 200 Ma (Burchfiel and Davis, 1971; Mueller and others, 1979). However, preliminary U–Pb zircon ages for these bodies are Late Jurassic (J.D. Walker, oral commun., 1993). Evidently, the hornblende contained excess argon, resulting in ages spuriously old. No Triassic U–Pb ages have been reported for plutons in the EMNSA, but few of the plutons of possible Triassic age have yet been dated by U–Pb methods. A dioritic orthogneiss unit in the Granite Mountains, assigned a probable Triassic age by Howard and others (1987), is now known to be Jurassic (Young and others, 1992). Small bodies of hornblende monzonite, commonly present between the Teutonia batholith and septa of Paleozoic marble in the western New York Mountains (fig. 26), is similar to Triassic monzonites known in the western Mojave Desert. This hornblende monzonite is younger than Paleozoic rocks and older than the informally named, Cretaceous Mid Hills adamellite of Beckerman and others (1982).

Triassic Sedimentary Rocks

In most of the ranges of the EMNSA that contain latest Proterozoic and Paleozoic sequences (see previous section entitled “Latest Proterozoic and Paleozoic Strata”), these strata are conformably overlain by reddish sandstone, limestone, and shaley limestone, or their metamorphosed equivalents. These rocks are correlated with the Early Triassic Moenkopi Formation (unit ₮m, pl. 1) according to Burchfiel and Davis (1971, 1977) and Walker (1987). In the Providence Mountains, this unit is approximately 300 m thick and contains Early Triassic fossils. In many ranges, these rocks are metamorphosed to distinctive calc-silicate rock (Stone and others, 1983).

In the Mescal Range, a unit of sandstone, shale, and limestone stratigraphically above the Moenkopi Formation and below a Jurassic sandstone unit was correlated with the Late Triassic Chinle Formation by Hewett (1956). This correlation was questioned by Marzolf (1983), who considered several Jurassic units to lie directly on the Moenkopi. Possible Chinle-correlative rocks have not been reported elsewhere in the EMNSA.

Mesozoic Volcanic and Hypabyssal Rocks

Several ranges within the EMNSA contain volcanic and volcaniclastic rocks, intercalated sedimentary rocks, and related hypabyssal rocks of Triassic and (or) Jurassic age. Stratigraphic sequences, in varying degrees of preservation, are exposed in four areas: the Mescal Range, the Old Dad Mountain-Cowhole Mountain-Soda Mountains area (the latter mountains are 1 to 5 km west of the EMNSA; see fig. 2), the New York Mountains, and the Providence Mountains. In a few other areas, metamorphosed or hydrothermally altered Triassic and (or) Jurassic volcanic, hypabyssal, and sedimentary rocks are present as roof rocks or pendants in Jurassic plutons or as slivers in fault zones. Among these small relicts, Jurassic rocks are probably more common than Triassic rocks. Owing to common metamorphism or alteration, as well as to lack of study, little is known about the petrology and geochemistry of Triassic and Jurassic volcanic rocks in the EMNSA.

A sequence of diverse volcanic and sedimentary rocks, more than 3 km thick, in Old Dad Mountain and the Cowhole Mountains consists of interbedded intermediate-composition to silicic lava flows and flow breccias, quartzarenite, sandstone and siltstone, sedimentary breccia and megabreccia, silicic ignimbrite, and other minor rock types (Marzolf, 1983, 1988, 1991; Busby-Spera, 1988; Busby-Spera and others, 1989). Zircon U–Pb ages of some of the volcanic rocks indicate that the age of this sequence is approximately 170 Ma, which is Middle Jurassic according to the geologic time scale of Harland and others (1989). A generally similar sequence of rocks is present in the Soda Mountains (Grose, 1959).

The quartzarenite units in the Mescal Range, the Cowhole Mountains, and at Old Dad Mountain are, in part, eolian. Until recently, these quartzarenites were generally correlated with the Early Jurassic (Peterson and Pipiringos, 1979) eolian Aztec Sandstone of the southern Great Basin and Navajo Sandstone of the Colorado Plateau. However, the U–Pb ages cited above indicate that the Jurassic quartzarenites in these ranges, and probably others in the EMNSA, may correlate with the Middle Jurassic Carmel Formation or Entrada Sandstone of the Colorado Plateau. Poor age constraints for the Colorado Plateau units permit either correlation.

In the Mescal Range, a unit of crossbedded arenitic sandstone approximately 250 m thick contains dinosaur tracks, the only dinosaur tracks known in California (Reynolds, 1983). This unit probably correlates with the Carmel Formation or Entrada Sandstone (included in unit Ja, pl. 1) in the Cowhole Mountains. The crossbedded arenaceous sandstone is overlain by a sequence, approximately 200 m thick, of basaltic, dacitic, and rhyolitic flow breccias and lava flows (Hewett, 1956; Fleck and others, 1994). These volcanic rocks have not been studied in detail, but they have been dated by K–Ar and Rb–Sr methods as Early Cretaceous, about 117 Ma (Fleck and others, 1994), and, therefore, differ in age as well as in composition from Jurassic volcanic sequences in other parts of the EMNSA.

In the New York Mountains, a sequence of metamorphosed volcanic rocks approximately 250 m thick overlies the Moenkopi Formation and is, in turn, overlain by a metasedimentary unit approximately 70 m thick (Burchfiel and Davis, 1977). The volcanic rocks are silicic in composition, include breccia or agglomerate, and contain subordinate intercalated metasiltstone and, near the base of the unit, metaconglomerate. The metasedimentary unit comprises siltstone, conglomerate, and tuffaceous sandstone and siltstone. The conglomerate beds contain clasts derived from the underlying volcanic unit. These two units could be either Triassic or Jurassic in age; the latter is more likely. The metavolcanic rocks are generally schistose or have fabrics that appear “mylonitic;” however, some of this fabric probably is partly inherited from original welded-tuff textures. Metasedimentary lithologies vary from argillite to schist. Both the volcanic and sedimentary units in the New York Mountains contain metamorphic biotite.

In the Providence Mountains, intermediate-composition to silicic volcanic and volcaniclastic rocks have been mapped by Hazzard (1954) and Goldfarb and others (1988). These igneous rocks, in part, overlie the Moenkopi Formation and are probably Triassic and (or) Jurassic in age (Walker, 1987). In some places, the volcanic rocks contain intercalated conglomerate and siltstone. Farther south in the Providence Mountains, hypabyssal rocks and probable volcanic rocks are present as roof rocks or septa adjacent to Jurassic plutons (Miller and others, 1985). These rocks are intensely altered, but some have granitic textures.

Jurassic and Cretaceous Plutonic Rocks

Introduction

Plutons known to be of Jurassic or Cretaceous age, on the basis of U–Pb geochronology, are common in the EMNSA (pl.1). Other plutons are definitely or almost certainly Mesozoic in age, but it is uncertain whether they are Jurassic or Cretaceous. The Jurassic and Cretaceous plutons, as well as the ranges in which they crop out within the EMNSA, are too numerous to list or describe individually. Rather, the descriptions below focus on typical or relatively well studied plutons and on features of special interest.

The Jurassic and the Cretaceous plutons within the EMNSA are small remnants or parts of larger magmatic belts that extend throughout much of the southern part of the North American Cordillera. The Jurassic and Cretaceous magmatic belts are oblique to each other (Tosdal and others, 1989; Miller and Barton, 1990; Fox and Miller, 1990). The northeast margin of the composite magmatic belt lies in the central parts of the Ivanpah and New York Mountains.

Known Jurassic plutons and Cretaceous plutons in the EMNSA region generally differ in petrology and geochemistry. Miller and others (1982, 1985), Howard and others (1987), and Fox and Miller (1990) have summarized the characteristics of Jurassic and Cretaceous plutonic rocks in the Granite Mountains, southern Providence Mountains, and Colton Hills, all in the southern part of the EMNSA. The Cretaceous granitoids are characterized by relatively low color index, white- to buff- or flesh-colored feldspars, and absence of clots of mafic minerals. In contrast, the Jurassic granitoids commonly are more heterogeneous, contain less quartz, more commonly are conspicuously sphene bearing, are more potassic, have higher color index, and contain lavender, gray, or pinkish alkali feldspar and clots of mafic minerals. In some places, Jurassic plutons are associated with magnetite-skarn deposits or zones of extensive albitization, neither of which has been documented for Cretaceous plutons. Thus, for some Mesozoic plutons for which U–Pb ages have not been determined, a reasonable inference as to a Jurassic or a Cretaceous age can be made from the overall petrology or composition of the plutons. Such estimates are probably most applicable to granodiorite and typical granite compositions and have a lower probability of being correct for either high-silica granite or dioritic or gabbroic rocks. In this report, we follow the IUGS classification scheme (Streckeisen, 1976) for plutonic igneous rocks.

Geochronologic data, much of it unpublished, for plutons in the EMNSA hint at multiple intrusive episodes for each of the Jurassic and Cretaceous groups of plutons. Many Jurassic plutons appear to be 170 to 160 Ma in age, but some plutons and dikes are as young as 150 to 145 Ma. Most of the Cretaceous plutons appear to belong to either a late Early to early Late Cretaceous intrusive event, from 100 to 90 Ma, or a late Late Cretaceous event, from 75 to 70 Ma. General distingushing characteristics of Jurassic and Cretaceous plutons are maintained despite episodicity within the two groups.

Jurassic Plutonic Rocks

Widespread emplacement of Jurassic plutons followed by approximately 50 m.y. the emplacement of scattered Triassic plutons in the Mojave Desert region (Tosdal and others, 1989; Anderson and others, 1992). The most thoroughly studied Jurassic plutonic rocks in the region of the EMNSA are those in the area of the southern Bristol Mountains (10 km south of the EMNSA; see fig. 2), southern Providence Mountains, and Colton Hills (Miller and others, 1985; Fox and Miller, 1990); Granite Mountains (Young and others, 1992); and Clipper Mountains (10 km south of the EMNSA) (Gerber and others, 1991). Three types of Jurassic plutonic rocks are common: mafic rocks; intermediate-composition to silicic, mixed or heterogeneous rocks; and leucocratic monzogranite (pl. 1). These plutons are difficult to date precisely but appear to be largely 170 to 160 Ma in age. Except for in the Granite Mountains where Late Jurassic diorite is known (Young and others, 1992), the mafic rocks are generally the oldest, and the leucocratic rocks, the youngest. Other plutons possibly in the 170– to 160–Ma age group are in the Old Dad Mountain and Devils Playground areas.

The mafic rocks include fine- to coarse-grained gabbro, diorite, and monzodiorite; common mafic minerals include clinopyroxene, hornblende, and biotite. In general, the mafic rocks have SiO_2 contents of 49 to 55 weight percent and are subalkaline and metaluminous. They also have relatively high abundances of large-ion lithophile elements (LILE), for example, commonly as much as about 3 weight percent K_2O and about 1,000 ppm Ba. Young and others (1992) concluded from geochemical modeling that diorite evolved from parental magma that was derived from hydrous, subcontinental lithosphere enriched in rare earth elements (REE) and was contaminated by mafic granulite in the lower crust as it ascended to the upper crust.

The mixed intrusive rocks are by far the most abundant. They are markedly heterogeneous, varying from fine-grained equigranular to coarsely porphyritic and from quartz monzodiorite to syenogranite and syenite. A number of phases or subgroups are present, typically bounded by gradational contacts. The mixed intrusive rocks have a wide range of SiO_2 contents, from 50 to 74 weight percent; they are subalkaline to, less commonly, alkaline, and metaluminous to weakly peraluminous. Some rocks are potassic, having K_2O/Na_2O ratios as great as 2. Abundances of Ba are as great as 2,000 to 4,000 ppm in some of the mafic and intermediate-composition rocks.

The leucocratic monzogranite is the most homogeneous of the three rock types. Whereas other plutonic phases grade complexly into one another, in general the monzogranite cleanly crosscuts as the youngest phase. In the Colton Hills, it comprises medium- to coarse-grained, porphyritic leucocratic biotite monzogranite, locally containing minor muscovite. It is subalkaline and generally moderately peraluminous. Trace-element abundances are unremarkable.

Many of the Jurassic plutonic rocks in the EMNSA are strongly altered. In the southern Providence Mountains and the southern Bristol Mountains, the rocks have undergone widespread albitization, characterized by the replacement of K–feldspar by albite and the continued stability of intermediate-composition plagioclase (Miller and others, 1985; Fox, 1989; Fox and Miller, 1990). This alteration is comparable to sodic-calcic alteration reported in some deep-seated porphyry-copper systems (see for example, Battles, 1991). Intense albitization is present as white zones in otherwise normally mesotype rocks; less intense albitization produces mottled patches or spots. Albitization is characterized by the doubling of Na_2O content and the nearly complete loss of K_2O: typically, K_2O decreases from 6 weight percent to less than 1 weight percent. Accompanying changes in Fe, Mg, and Ca abundances depend on the extent of chloritization of mafic phases. During alteration, Al, Ti, Zr, Y, and REE are generally immobile on a hand-specimen scale. Alteration was probably caused mainly by repeated intrusion of magma into the shallow crust, which generated large, long-lived hydrothermal systems.

Late Jurassic plutons in the EMNSA are known in the Granite and Ivanpah Mountains and may be more widely present. Diorite in the Granite Mountains is about 155 Ma in age on the basis of U–Pb zircon ages (Young and others, 1992). Other than its younger age, the diorite is similar to diorite in the Providence and Bristol Mountains. The informally named Ivanpah granite of Beckerman and others (1982) (unit Ji, pl. 1) is 150 to 145 Ma in age, also on the basis of U–Pb zircon ages (J.D. Walker, oral commun., 1992). It consists of biotite monzogranite that is strongly porphyritic. The pluton is moderately peraluminous and potassic. A similar peraluminous pluton in the Providence Mountains near Tough Nut Spring is less porphyritic but is possibly related to the Ivanpah pluton (Goldfarb and others, 1988).

Late Jurassic Dikes

In the southern Providence Mountains, swarms of Middle to Late Jurassic intermediate-composition to silicic dikes intrude Jurassic plutons (Miller and others, 1985). The dikes vary from dacite porphyry to aphanitic rhyodacite to aplite. Similar intermediate-composition dikes in the Colton Hills are intruded by Cretaceous plutons (Fox and Miller, 1990). Dikes in the Colton Hills have a minimum age of 146 Ma by K–Ar methods on biotite (D.M. Miller, unpub. data, 1984). Similar dikes are known in a few other places within the EMNSA, such as the Cowhole Mountains. Possibly related swarms of Late Jurassic mafic or intermediate-composition to silicic dikes are widespread in eastern California and southwestern Arizona (Chen and Moore, 1979; Powell, 1981; Karish and others, 1987; Hopson, 1988; Haxel and others, 1988; Tosdal and others, 1989). Some Jurassic dikes that crop out in the Providence Mountains were correlated by James (1989) with the approximately 150–Ma Independence dike swarm of eastern California. James (1989) suggested that the more than 500–km-long dike swarm may be related to either continental-scale arc-normal extension, changes in plate motions, or oblique subduction combined with left-lateral shear. The similar age of the informally named Ivanpah granite of Beckerman and others (1982) raises the possibility that plutons were also emplaced at the time of dike intrusion.

Cretaceous Plutonic Rocks

Most Cretaceous plutonic rocks in the EMNSA belong to the Early and Late Cretaceous Teutonia batholith (Beckerman and others, 1982). Beckerman and others (1982) considered the Teutonia batholith to be Jurassic and Cretaceous in age, chiefly on the basis of K–Ar cooling ages that provide minimum emplacement ages. They divided the batholith into seven informally named plutons; a large area of granitic rocks in the hills near Halloran Spring (DeWitt and others, 1984) remains undivided and undescribed (fig. 26). One pluton is Jurassic in age, the informally named Ivanpah granite of Beckerman and others (1982) (pl. 1). The other six plutons, which constitute most of the eastern part of the batholith, are Cretaceous in age. Preliminary U–Pb zircon ages for major plutons of the batholith range from 93 to 100 Ma (E. DeWitt, oral commun., 1990). Thus, the Teutonia batholith is hereby redefined to exclude the coincidentally spatially associated, Jurassic Ivanpah granite; this revised usage is followed in the summary below.

The six major plutons that constitute the eastern Teutonia batholith crop out chiefly in the New York Mountains, Mid Hills, and the Cima Dome-Wildcat Butte-Marl Mountains area (fig. 26; pl. 1). Five of the six plutons are fairly large, having exposed areas of about 50 to 200 km^2. These plutons are intermediate to felsic in composition; in places, they form craggy exposures and also include volumetrically minor dikes (fig. 27). The sixth pluton is of mafic composition and forms a subcircular outcrop area about 2 km in diameter; bodies of correlative composition are smaller. Similar mafic to felsic rock units have been noted in the hills near Halloran Spring (E. DeWitt and H.G. Wilshire, oral commun., 1992).

The five relatively large plutons of the Teutonia batholith mostly vary in composition from quartz monzodiorite to syenogranite; granodiorite and monzogranite are the principal compositional types; monzodiorite is a minor phase of one pluton. Despite this compositional range, granite constitutes most of the exposed rocks. Quartz-poor modal compositions (quartz monzodiorite, quartz monzonite, and quartz syenite) are present only in the Rock Spring monzodiorite of Beckerman and others (1982) (unit Krs, pl. 1). Other rocks are medium to coarse grained; some plutons or facies within plutons are equigranular, whereas others have alkali-feldspar phenocrysts. Biotite is ubiquitous; hornblende is common to absent. The Kessler Springs pluton locally contains minor primary muscovite. Three of the five plutons are leucocratic, having color indices less than 5: the Teutonia adamellite (Kt), Mid Hills adamellite (Kmh), and Kessler Springs adamellite of Beckerman and others (1982) (Kks).

The mafic pluton (Black Canyon hornblende gabbro of Beckerman and others (1982) (Kbc), which is presumably associated with the Teutonia batholith, comprises compositionally and texturally variable, hornblende-rich mesotype to melanocratic gabbro. Magnetite content is high: average is 6.5 volume percent. This phase of the batholith is intruded by two of the more widespread granitic phases of the Teutonia batholith, the Mid Hills adamellite and the Rock Spring monzodiorite. Probable correlative bodies include one in Cedar Canyon and another, not shown on plate 1, near Wildcat Butte on Cima Dome.

The six plutons of the Teutonia batholith form a broadly calc-alkaline series (Beckerman and others, 1982). The hornblende gabbro contains 43 to 49 weight percent SiO_2; the other five plutons range from 68 to 77 weight percent SiO_2. The granitoid plutons generally straddle the boundary between metaluminous and peraluminous compositions. Moderately or strongly peraluminous granites are absent. Abundances of Ba, Sr, and Rb (the only trace elements analyzed) are generally normal and unremarkable for granitic rocks.

Geobarometric data indicate that the Rock Spring monzodiorite of Beckerman and others (1982) was emplaced at pressures of from less than 1 to 3 kb (Anderson and others, 1988, 1992), corresponding to upper-crustal depths of approximately less than 3 to 10 km. According to J.L. Anderson (oral commun., 1990), present exposures provide a tilted view of the batholith: the shallowest plutons, emplaced at pressures of approximately 0.5 kb, are to the north, and the deepest plutons, emplaced at approximately 3 kb, are to the south. However, these pressure data conflict with geologic evidence that the roof of the batholith is exposed in the south (Goldfarb and others, 1988) as a shallowly south dipping surface in the Providence and Marl Mountains; therefore, the south should be the shallowest part of the batholith. The Teutonia batholith is among the shallowest of the Mesozoic plutonic complexes in the Mojave Desert region (Anderson and others, 1988, 1992); pressure estimates for ten other complexes range from 2 to 9 kb.

Small, shallow-level stocks northeast of the Teutonia batholith appear to represent outliers of the magmatic belt formed in earliest Late Cretaceous time. Magmatic alteration, intrusive breccia, and felsite dikes in the Colosseum Mine area of the Clark Mountain Range (described in subsection below entitled “Breccia Pipe and Related Deposits”) are about 100 Ma in age (Sharp, 1984). Similar alteration and breccia, as well as small hypabyssal bodies of biotite granodiorite, lie about 5 km northeast of the EMNSA in the New York Mountains, near Crescent Peak (Miller and Wooden, 1993). This granodiorite yielded a K–Ar biotite age of 94.4±2.4 Ma.

Latest Cretaceous plutons in the EMNSA range from 75 to 70 Ma in age (Howard and others, 1987; J.L. Wooden, oral commun., 1987, *quoted in* Fox and Miller, 1990). Late Cretaceous plutons, known to be approximately 70 Ma, crop out in the Granite Mountains and at Homer Mountain (5 km east of the EMNSA); probable Late Cretaceous plutons crop out in the Fenner Hills and near Bobcat Hill. In the Granite Mountains, a suite of Cretaceous igneous rocks includes a granodiorite pluton and a larger, compositionally zoned pluton, as well as granite, aplite and pegmatite dikes (Howard and others, 1987). The granodiorite pluton makes up most of the western Granite Mountains (pl. 1); the zoned pluton makes up the southeastern part of the Granite Mountains (Howard and others, 1987) and part of the adjacent Providence Mountains (Miller and others, 1985).

Magmatic biotite from the zoned pluton yielded K–Ar dates, possibly emplacement ages, of 74.5 to 70.9 Ma (Miller and others, 1985; Howard and others, 1987). In general, latest Cretaceous plutonic rocks are silicic, weakly to strongly peraluminous granites.

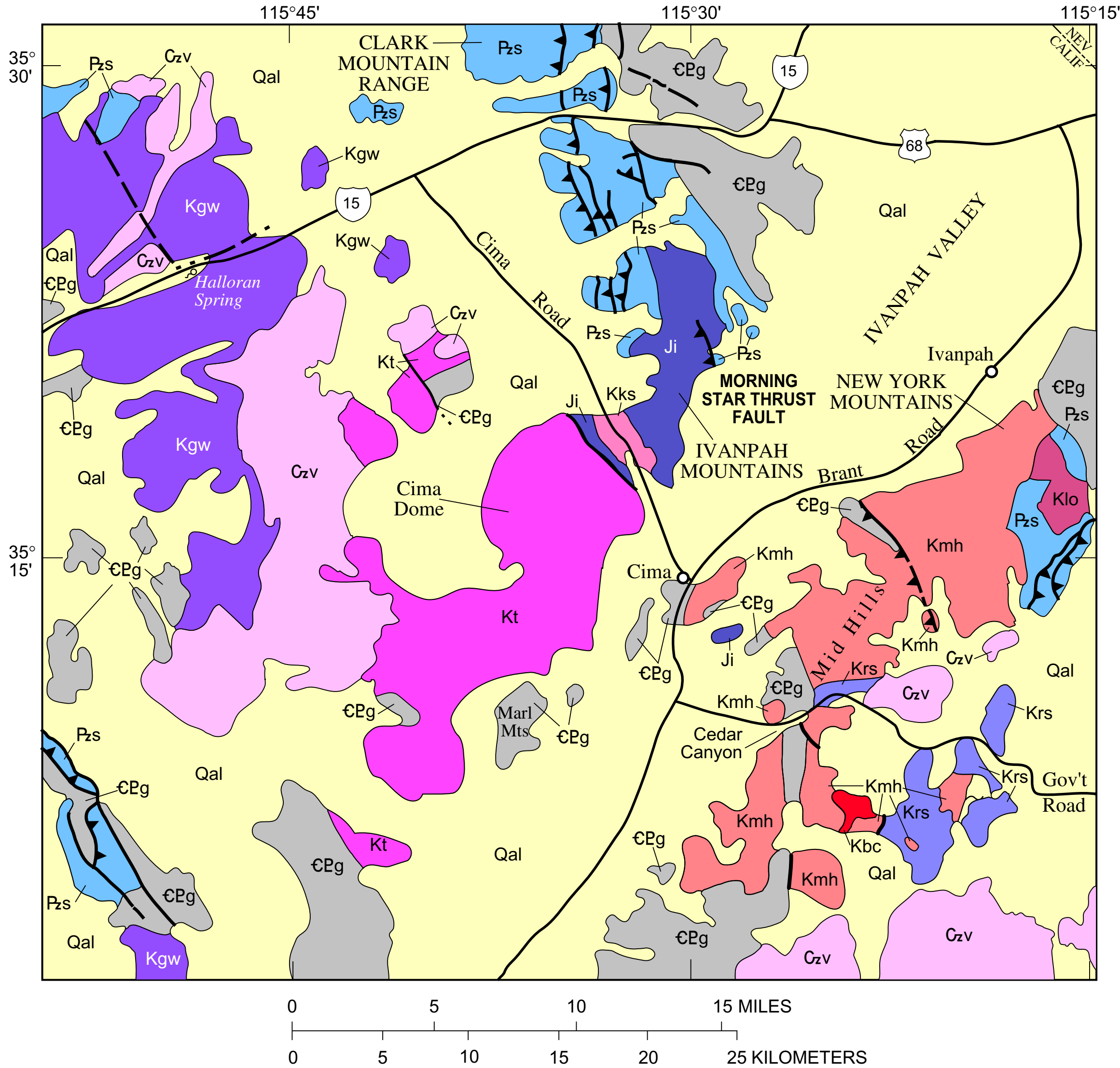
Mesozoic Deformation

Mesozoic deformational features of regional extent crop out in the western and north-central parts of the EMNSA. These deformational features are reflections of crustal shortening, as shown by brittle-style deformation of thrust plates, which have developed in the foreland of the Cordilleran thrust belt (Burchfiel and Davis, 1971, 1977, 1981; Snoke and Miller, 1988). Ductile-style nappes in southeastern California and Arizona extend to the south border of the EMNSA (Howard and others, 1980; Miller and Barton, 1990).

Generally east directed thrust faults, present in the Cowhole Mountains and Clark Mountain Range areas, may be Middle Triassic(?) through Early Jurassic in age (Burchfiel and Davis, 1981). Burchfiel and Davis (1981) interpreted metamorphosed Paleozoic rocks in the Cowhole Mountains as having been thrust eastward and then overlapped unconformably by the Early Jurassic Aztec Sandstone (unit Ja, pl. 1). However, Busby-Spera (1988) and Busby-Spera and others (1989) presented evidence that the sandstone is Middle Jurassic in age and may have accumulated in an intra-arc graben. In the Clark Mountain Range, some east-directed thrust faults are cut by small dioritic plutons, which were originally dated at 200 to 190 Ma by K–Ar methods (Burchfiel and Davis, 1981) but are now known to be Late Jurassic in age. Latest Early Cretaceous thrusting placed Paleozoic strata over Early Cretaceous volcanic rocks. This thrust was then intruded by plutons of the mid-Cretaceous Teutonia batholith (Burchfiel and Davis, 1971, 1981; Fleck and others, 1994). A similar sequence of faulting, although not as well chronologically constrained, is present in the New York Mountains.

Contrasting with the thrust faults and folds that represent horizontal shortening are complexes of normal faults, in places accompanied by stratal tilting, that represent horizontal extension. Best documented period of extension is of Middle Jurassic age in the Cowhole Mountains and probably of a similar age in the Providence Mountains. In the former location, normal faults are interpreted by Busby-Spera (1988) and Busby-Spera and others (1989) as being active during extension of Middle Jurassic lava flows. In the Providence Mountains, Hazzard (1954) mapped four sets of normal faults, all but the youngest of which are cut by rhyolite dikes dated as Jurassic (J.D. Walker, oral commun., 1993). For both the Cowhole Mountains and Providence Mountains, most normal faults strike north, suggesting east-west extension.

In summary, Mesozoic deformation is incompletely understood. Available evidence points to Middle Jurassic or older thrusting, Middle Jurassic localized extension, and Late Jurassic to Early Cretaceous thrusting.



EXPLANATION

Qal	Alluvium (Quaternary)
Czv	Volcanic rocks (Cenozoic)
	Teutonia batholith (Cretaceous and Jurassic)—Divided into informally named units by Beckman and others (1982)
Kmh	Mid Hills adamellite (Cretaceous)
Kt	Teutonia adamellite (Cretaceous)
Klo	Live Oak Canyon granodiorite (Cretaceous)
Kks	Kessler Springs adamellite (Cretaceous)
Kbc	Black Canyon horblende gabbro (Cretaceous)
Kgw	Granitic rocks, undivided (Cretaceous)
Krs	Rock Spring monzodiorite (Cretaceous)
Ji	Ivanpah Granite (Jurassic)
Pzs	Sedimentary rocks (Paleozoic)
ЄPg	Banded and quartzofeldspathic gneisses (Cambrian and Proterozoic)
	Contact
	Fault—Dashed where approximately located; dotted where concealed
	Thrust Fault—Dashed where approximately located. Sawteeth on upper plate

Figure 26. Geologic map of north-central part of East Mojave National Scenic Area, Calif., showing distribution of various phases of Teutonia batholith. Modified from Beckerman and others (1982).

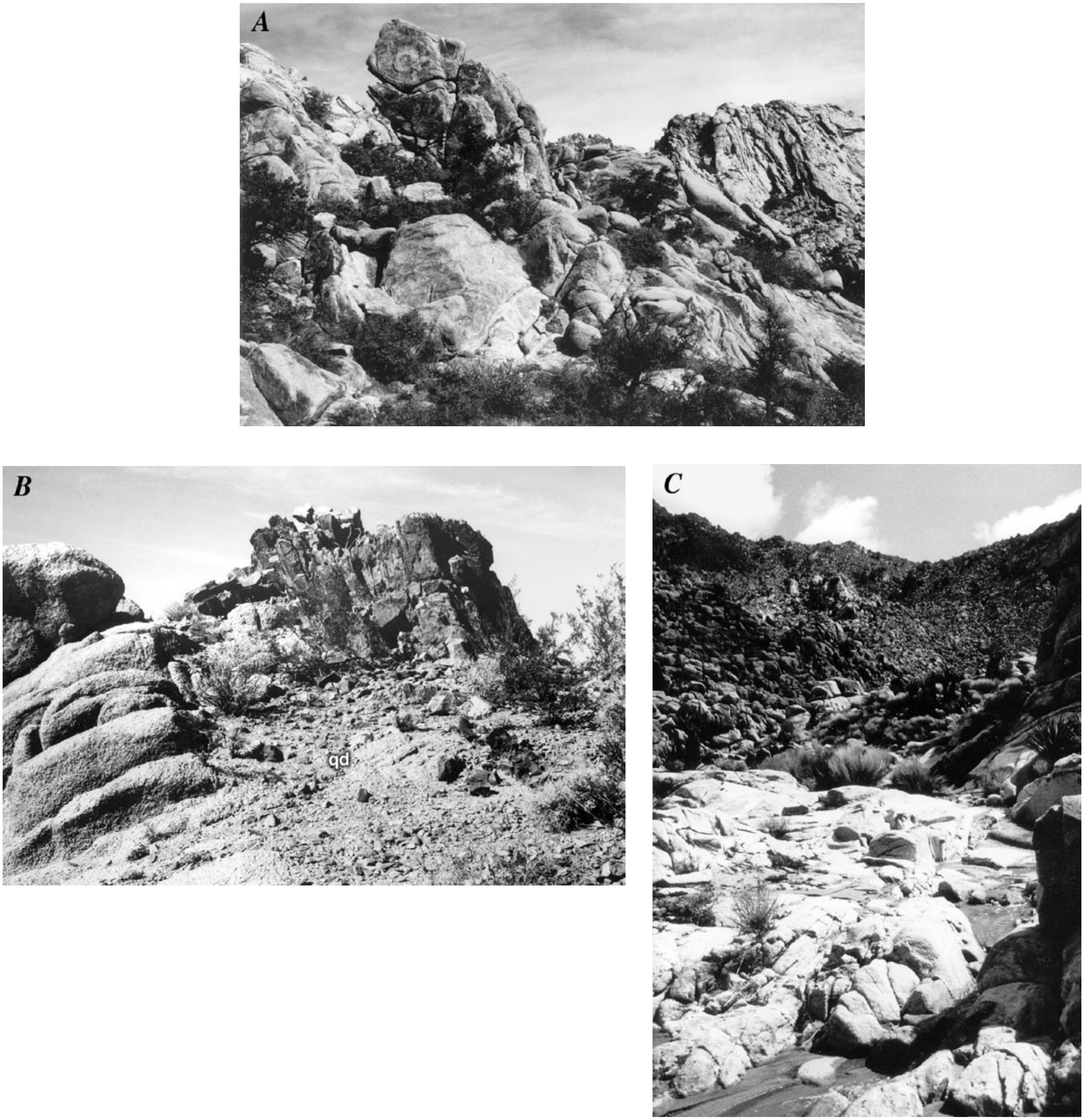


Figure 27. Typical exposures of two plutonic phases of Teutonia batholith, East Mojave National Scenic Area, Calif. *A*, Informally named Mid Hills adamellite of Beckerman and others (1982) (unit Kmh, pl. 1) near Giant Ledge Mine. View to east. Bold exposures in left-center of field of view are approximately 40 m high. *B*, Coarsely crystalline phase of informally named Teutonia adamellite of Beckerman and others (1982) (unit Kt, pl. 1) to left, cut by narrow hornblende quartz diorite dike (qd), in center, in northern part of Cima Dome (fig. 26). Width of dike is approximately 10 m. *C*, Latest Cretaceous granite in southern Providence Mountains (fig. 2) forms white, bouldery-appearing outcrops. Top of ridge is underlain by Jurassic granitoids.